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# A SYSTEM FOR MEASURING THERMAL EXPANSION OF METALLIC AND NON-METALLIC MATERIALS AT CRYOGENIC TEMPERATURES

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~~ABSTRACT~~

This report describes the development of a cryogenic system for measuring thermal expansion. The repeatability of determinations made with this apparatus has been demonstrated.

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### A SYSTEM FOR MEASURING THERMAL EXPANSION OF METALLIC AND NON-METALLIC MATERIALS AT CRYOGENIC TEMPERATURES

#### SUMMARY

Large space vehicles contain many hundreds of feet of weldments. These joints must maintain the structural integrity of the vehicle at temperatures ranging from ambient to that of liquid hydrogen. Of course, other portions of the vehicle are subjected to extremely high temperatures. Thus, the need for a better understanding of the expansion characteristics of materials used in these large structures is obvious. This report describes the development of a cryogenic system for measuring thermal expansion. The repeatability of determinations made with this apparatus has been demonstrated.

#### INTRODUCTION

The design and construction of large launch vehicles create many expansion problems which do not exist in smaller and less complicated devices. The size alone emphasizes the importance of joined materials having essentially the same expansion characteristics. Temperature changes and vibration make the problems even more critical. Knowledge of the expansion coefficients of metals, welded joints, and gasket materials is needed over a wide temperature range. Therefore, a program was initiated to develop a system capable of measuring changes in specimen length in the microinch range. To accomplish this, an apparatus consisting of a quartz dilatometer, the associated cryostat, and necessary instrumentation has been designed. Movements of the dilatometer are measured with a commercial interferometer. The same cryostat and vacuum system are used to determine the expansion characteristics of metallic and non-metallic materials. Only the specimen holders and respective auxiliary fixtures are changed for the various types and sizes of specimens.

Even though very good measurements were made, too much time was required when using the interferometer. Therefore, the optical system was replaced with an electronic measuring system that is based on differential transformers. These changes are described in detail in this report.

## DISCUSSION

### THE LIQUID NITROGEN CRYOSTAT AND ASSOCIATED EQUIPMENT

FIG 1 is a drawing of the original dilatometer design. In this design, the dilatometer was supported on the bottom of the vacuum chamber. Initial measurements made with the dilatometer as originally designed were only partially successful because the boiling cryogenic vapors emanating from the dewar located immediately below the vacuum chamber caused random thermal contraction in the bottom of the vacuum chamber. This difficulty was overcome by supporting the dilatometer from the top of the vacuum chamber as shown in FIG 2. The critical components of the system are shown in FIG 3. The specimen, A, is located at the bottom of a quartz tube B. A quartz rod, C, is placed inside the quartz tube on top of the specimen. This rod passes through an inner collar D to an inner holder E. The bottom optical flat F is supported on the inner holder. The top optical flat G is mounted to the top of the vacuum chamber. Nichrome wire heaters are wound around the bottom of the quartz tube at the test specimen location. As a specimen is heated and it expands, the lower optical flat is moved nearer to the top flat. This change in distance is measured with an interferometer. The interference of light from the top of the lower optical flat and light from the bottom of the top flat causes a movement of alternate light and dark lines, or fringes, across a reference mark on the interferometer. These fringes are counted for a period of time, corresponding to a known change in specimen temperature. The coefficient of linear expansion is then determined by the relationship

$$C = \frac{\Delta L}{L \Delta t} = \frac{.0000273 \text{ cm} \times N}{L \times \Delta t}$$

where

C = Linear Coefficient of Expansion

$\Delta L$  = Total Change in Specimen Length

L = Initial Length of Specimen

t = Temperature Range of Test

.0000273 cm = 1/2 Wave Length of Green Mercury Light

N = Number of Fringes Counted.

Excellent determinations of expansion were made with this cryostat; however, the temperature range was limited.

## THE LIQUID HELIUM CRYOSTAT AND ASSOCIATED EQUIPMENT

The dilatometer and other instrumentation for the first liquid helium cryostat were essentially the same as for the nitrogen system. A major difficulty was experienced with the arrangement (FIG 4). Excessive heat flow from the large, massive top portion of the vacuum chamber through the quartz tube, the fill tube, and the lower section of the vacuum chamber into the cryostat made it essentially impossible to keep liquid helium in the dewar. Under these conditions, the minimum stable temperature attainable was approximately  $30^{\circ}\text{K}$  ( $-243^{\circ}\text{F}$ ). Therefore, a major design change was made. The diameter of the lower portion of the vacuum chamber was decreased, which reduced the amount of heat flowing to the specimen. The dilatometer, the lower portion of the vacuum chamber, and the dewars were increased from 12 to 36 inches in length. The increased volume of helium and increased distance from the heat leaks corrected the original difficulty. This improved cryostat, shown in FIG 5, made it possible to maintain the specimen temperature at  $4^{\circ}\text{K}$  ( $-269^{\circ}\text{F}$ ).

A second modification was the replacement of the optical system with an electronic measuring device. This system is based on a differential transformer as the sensing element of the dilatometer. The signal from this transformer is recorded easily, thus saving time and eye strain. FIG 5 shows the cross-sectional view of the differential transformer and its location in the apparatus. Table 1 shows some typical values for the expansion of different materials over various temperature ranges.

## CONCLUSIONS

The system described in this report proved to be a very effective method of measuring the thermal expansion of both metallic and non-metallic materials at cryogenic temperatures. Reproducible data at cryogenic temperatures down to  $4^{\circ}\text{K}$  ( $-269^{\circ}\text{F}$ ) have been obtained. The equipment is sufficiently simple to permit non-professional employees to generate data routinely.

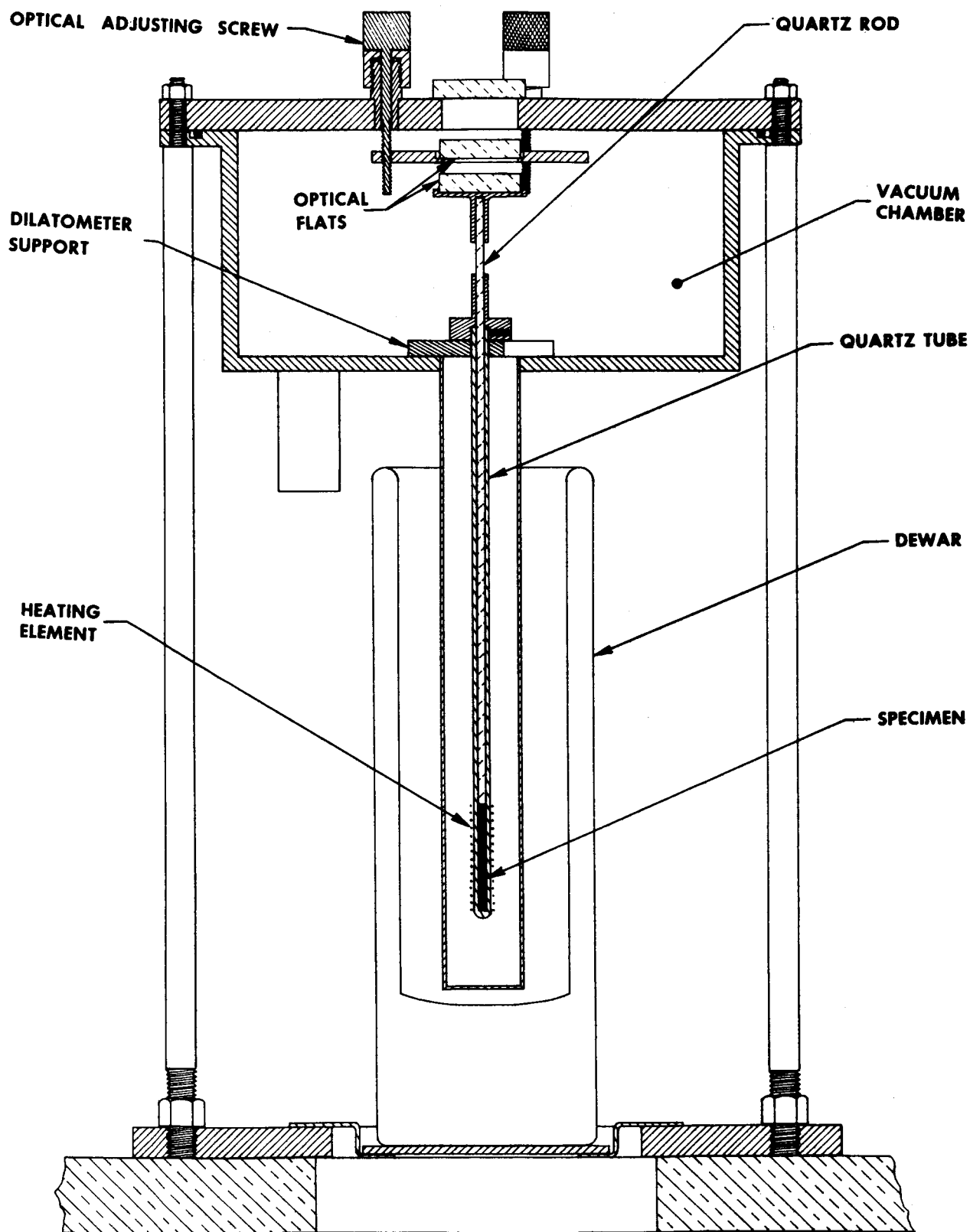
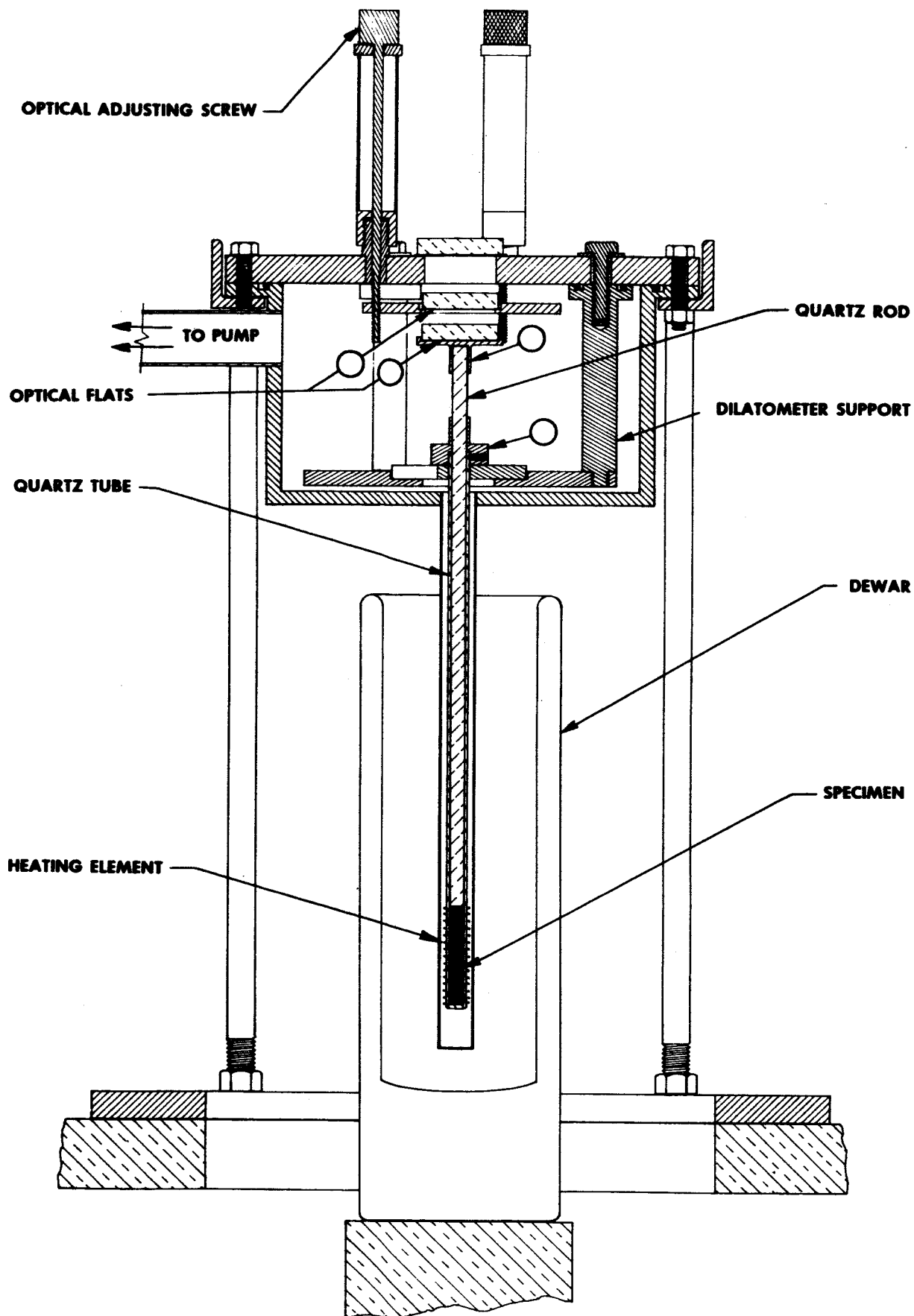
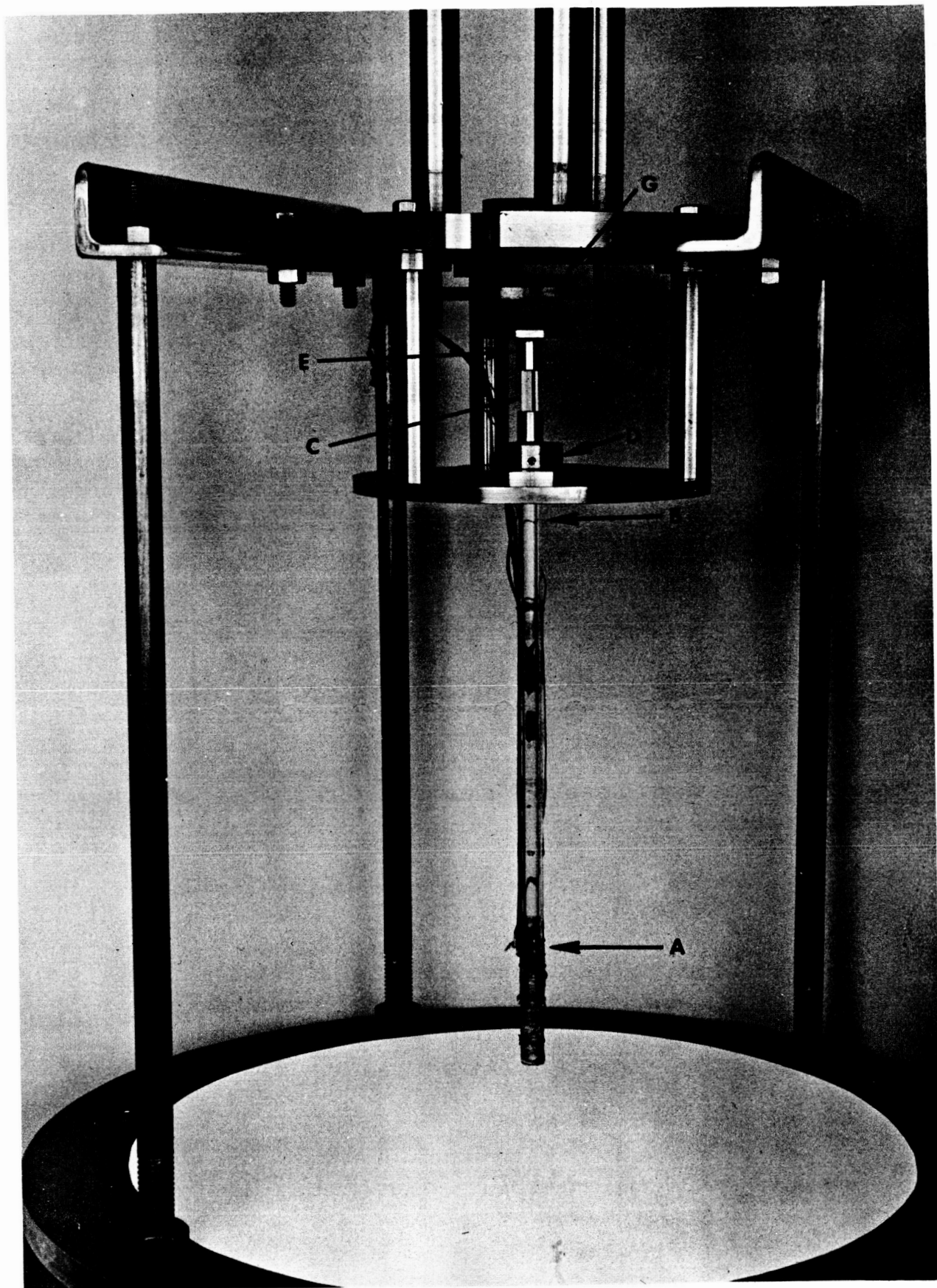


FIGURE 1 CROSS SECTION OF DILATOMETER SUPPORTED ON  
BOTTOM OF VACUUM CHAMBER



**FIGURE 2 CROSS SECTION OF DILATOMETER SUPPORTED BY TOP OF VACUUM CHAMBER**



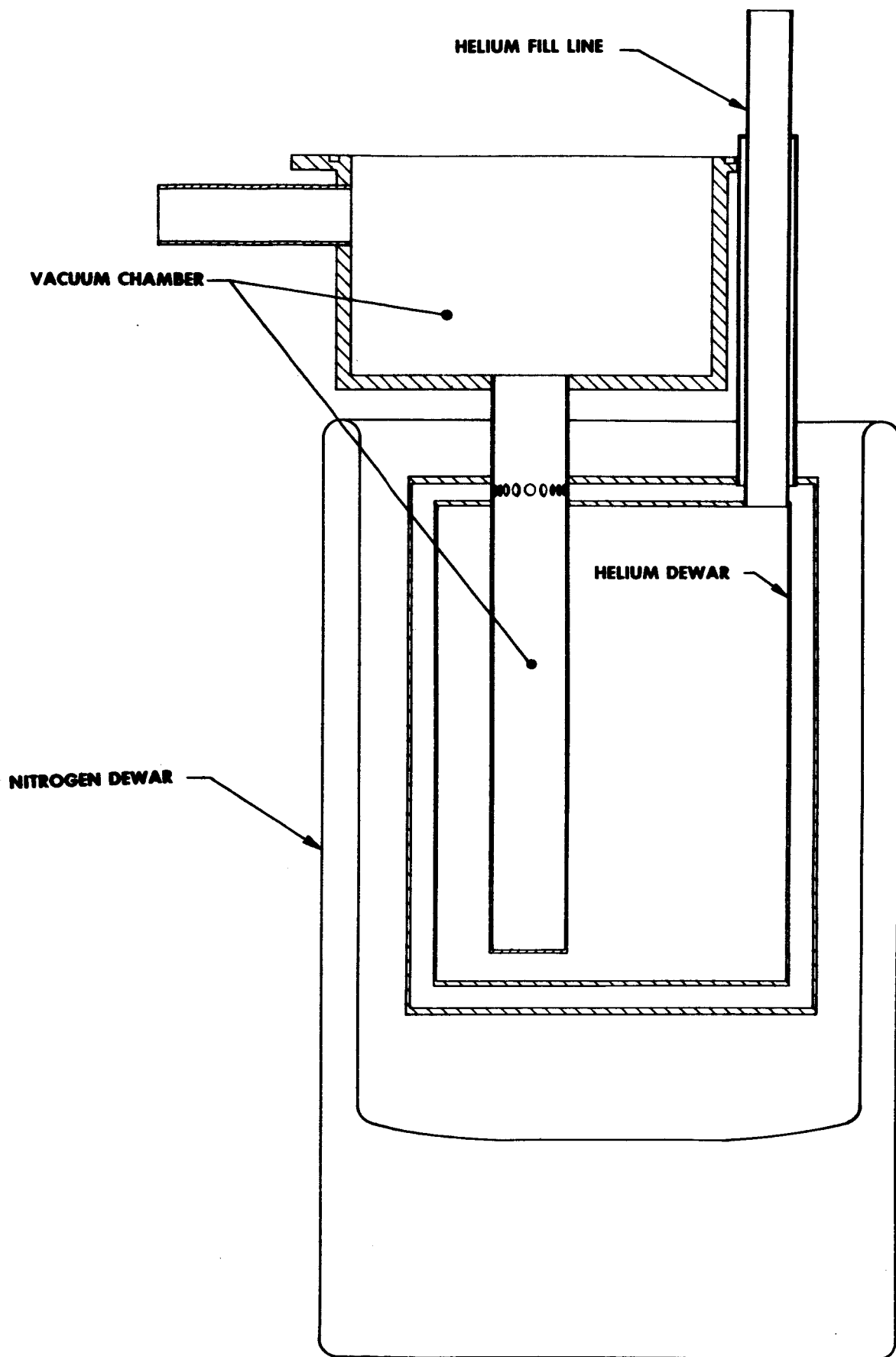


FIGURE 4 CROSS SECTION OF FIRST HELIUM CRYOSTAT

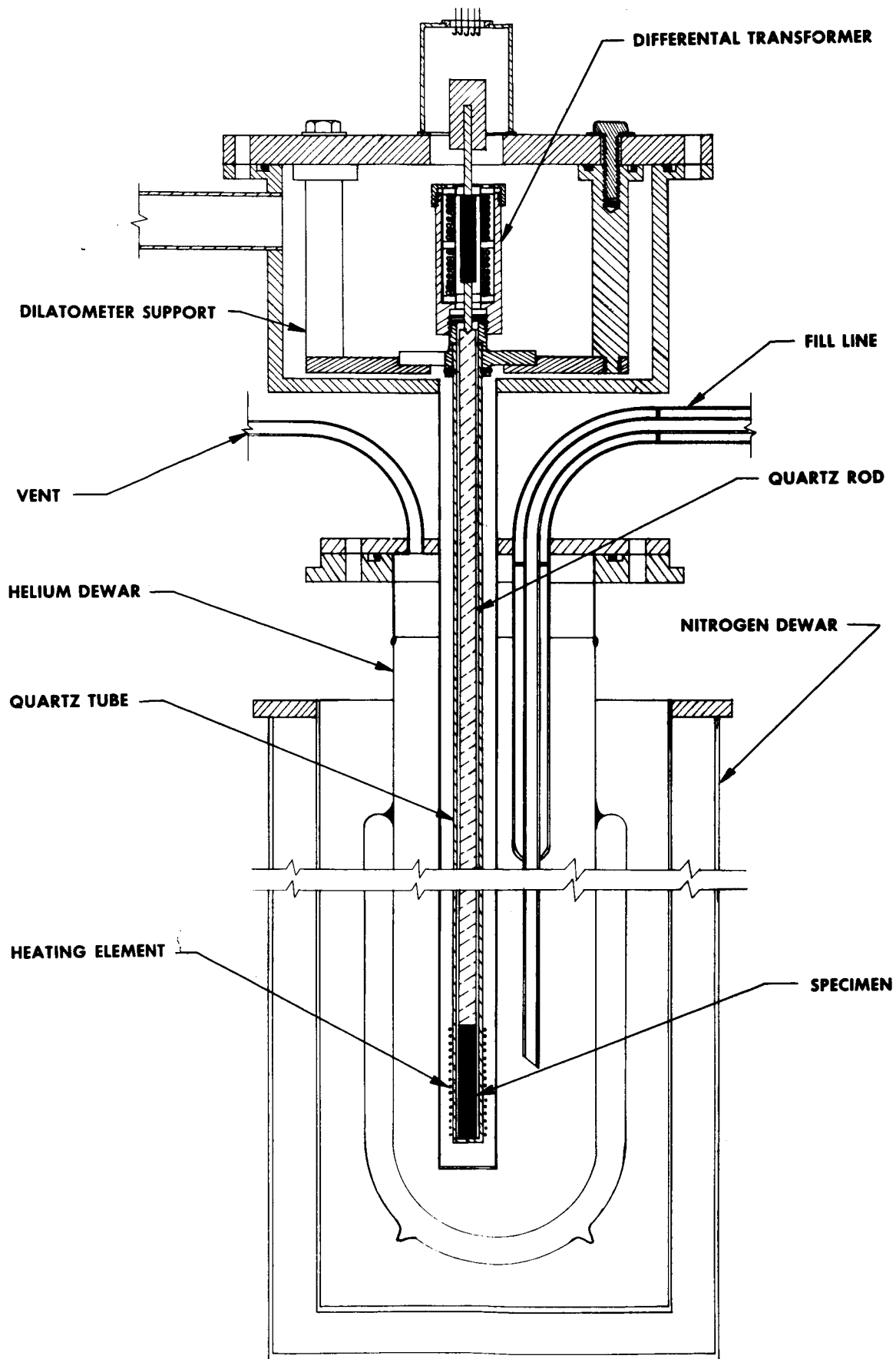


FIGURE 5 CROSS SECTION OF 3-FOOT HELIUM CRYOSTAT  
AND DIFFERENTIAL TRANSFORMER

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APPROVAL


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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified. This document has also been reviewed and approved for technical accuracy.

  
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TABLE 1

## COEFFICIENTS OF LINEAR EXPANSION

$$\frac{1}{L} \frac{dL}{dT}, \text{ per } ^\circ\text{C (X } 10^{-6})$$

MATERIAL	-240°C to -227°C	-240°C to -190°C	-240°C to +25°C	-190°C to -114°C	-114°C to +25°C	-190°C to +25°C
2219-T87 Aluminum					17.4	
6061-T6 Aluminum	2.2	3.29	17.3			20.4
2319 Aluminum					17.8	
Electrolytic Copper (Tough Pitch)					15.5	
Am-Pre-Loy (Copper- Aluminum Alloy)				13.8	15.9	
Fluorogreen E-600 #1				7.3	53.4	
Fluorogreen E-600 #2				38.6	117.9	83.9
Fluorogreen E-600 #3				35.8	119.8	
Fluorogold #1				6.4	64.5	43.4
Fluorogold #2				6.3	82.6	
Impregnated Allpax #1				8.4	12.4	
Impregnated Allpax #2				9.0	13.3	12.4

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